(12) UK Patent Application (19) GB (11) 2 064 877 A

(21) Application No 8036807
(22) Date of filing 17 Nov 1980
(30) Priority data
(31) 7940382
(32) 22 Nov 1979
(33) United Kingdom (GB)
(43) Application published 17 Jun 1981
(51) INT CL[3] H01Q 21/08
(52) Domestic classification H1Q BA
(56) Documents cited None
(58) Field of search H1Q

(71) Applicants
The Secretary of State for Defence,
Whitehall,
London SW1A 2HB.
(72) Inventors
Peter Scott Hall
(74) Agents
M. Greenhill,
Procurement Executive,
Ministry of Defence,
Patents 1 A (4),
Room 1932,
19th Floor,
Empress State Building,
Lillie Road,
London SW6 1TR.

(54) **Microstrip antenna**

(57) A wide-band log periodic microstrip antenna comprises a feed-line (5) having a succession of conducting sheet radiators (13) spaced along it from the input end (6). Each radiator is resonant at a frequency lower than its predecessor by a constant factor and the spacing between adjacent radiators, in terms of the wavelength at their mean resonant frequency, is such that they resonate approximately in phase, thereby producing a main beam normal to the plane of the microstrip. The couplings between each radiator and the feed-line are equal and non-direct (not DC), and are provided by either locating the radiators alongside the feed-line, on the microstrip substrate, or overlying the feed-line and spaced therefrom by a layer of dielectric material. Desirably the substrate thickness, the feed-line width and the aforesaid layer thickness increase progressively along the feed-line.

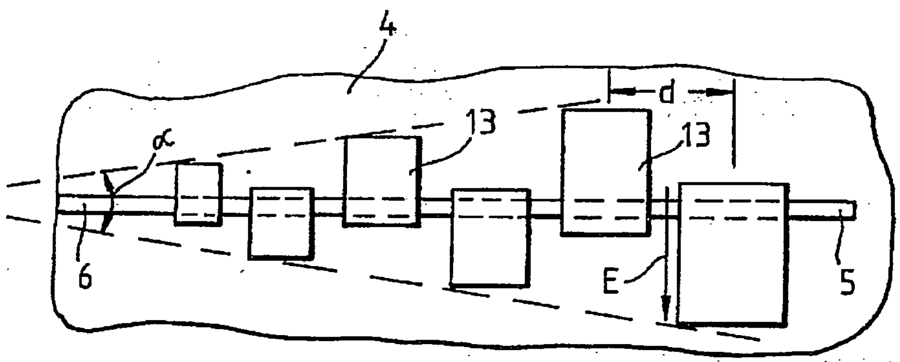


Fig.4.

The mathematical formula appearing in the printed specification was submitted after the date of filing, the formula originally

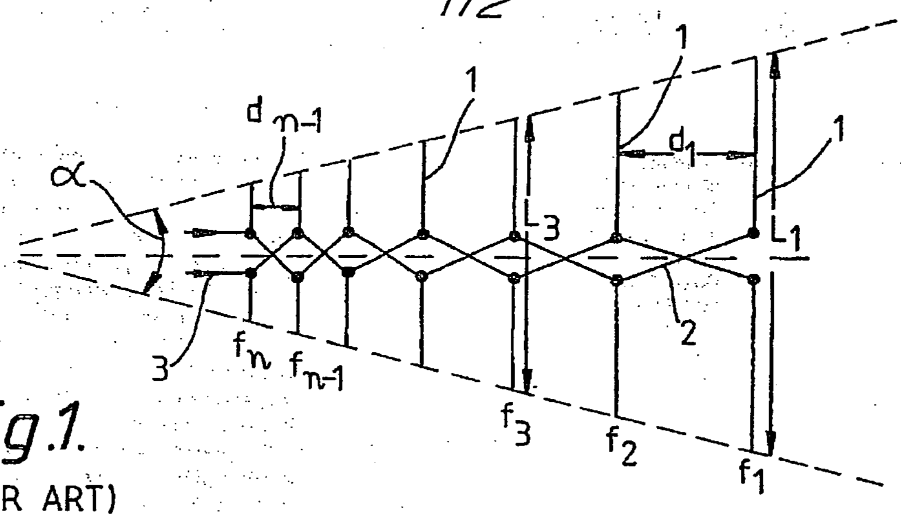


Fig.1.
(PRIOR ART)

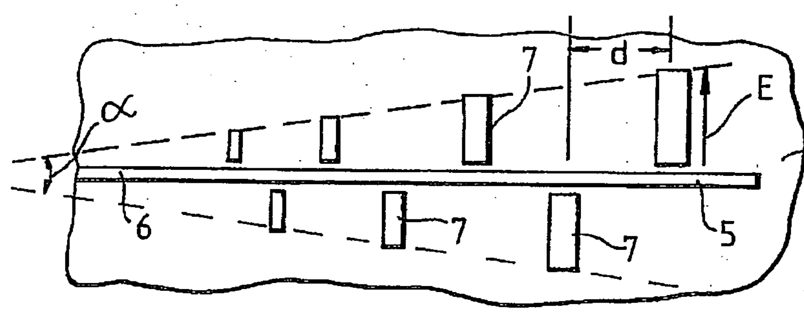
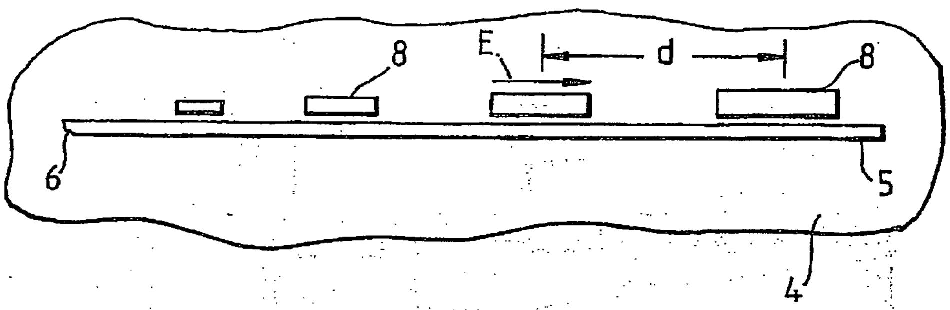


Fig.2.

Fig.3.



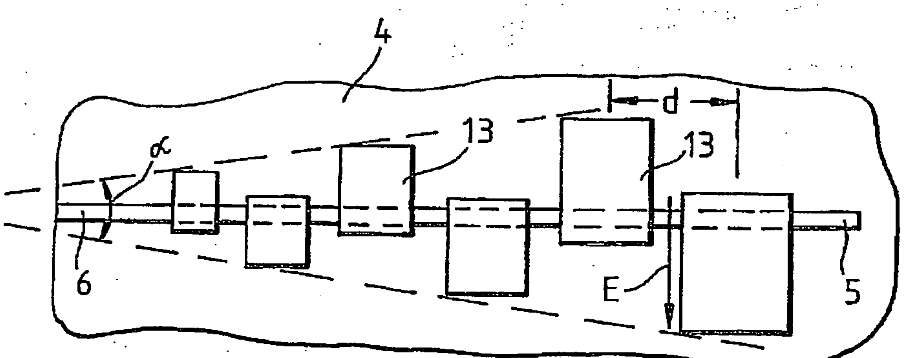


Fig.4.

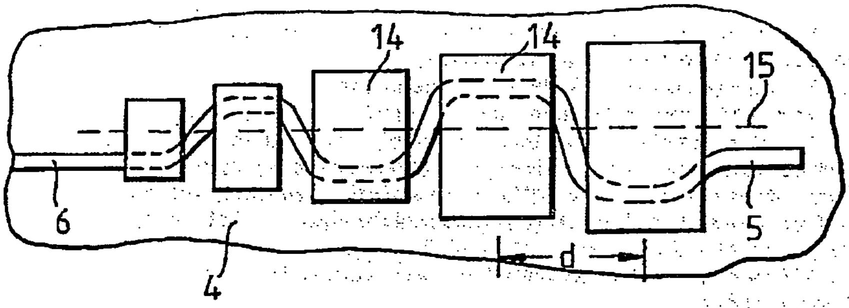
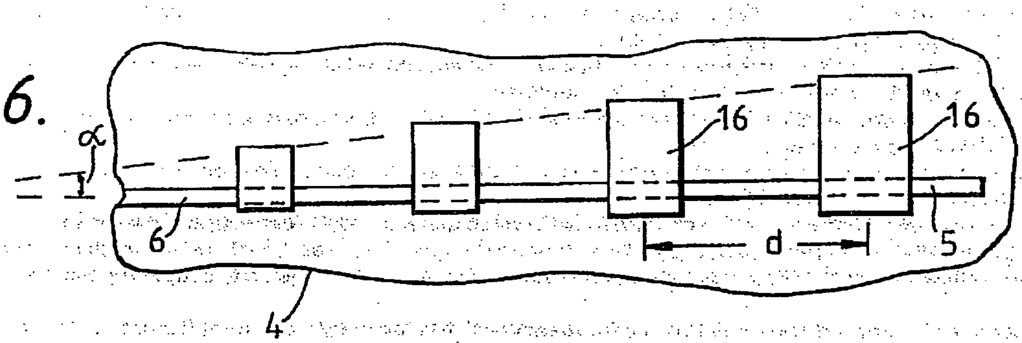


Fig.5.

Fig.6.



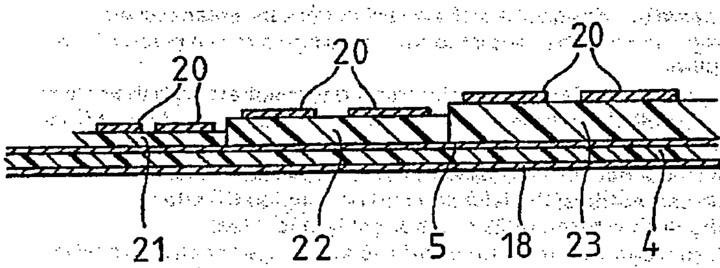
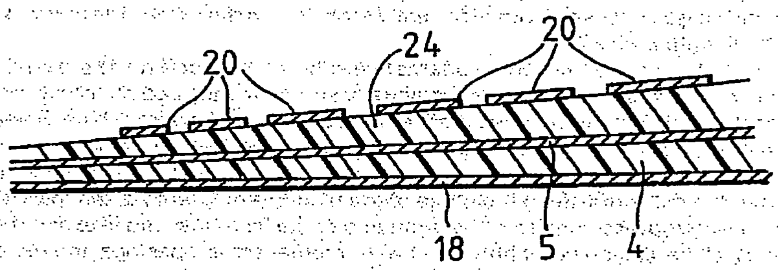


Fig.7.

Fig.8.



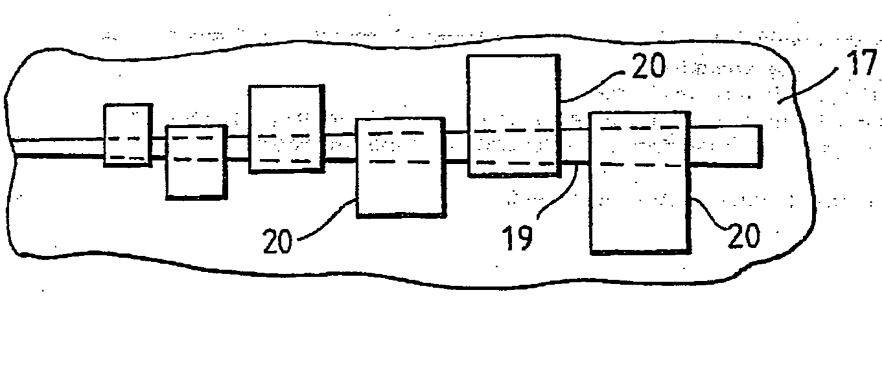


Fig.9.

SPECIFICATION

Improvements in or relating to microstrip antennas

This invention relates to microstrip antennas, in particular to microstrip antennas whose characteristics are approximately or substantially independent of frequency over a wide band.

An example of a known frequency-independent antenna is the log periodic dipole array. The latter is not a microstrip antenna but comprises a plurality of dipoles shunt-connected along a two-wire transmission line, each successive dipole (starting from the input end of the line) being resonant at a slightly lower frequency than its predecessor. The spacing between successive dipoles is approximately one quarter wavelength (related to the mean resonant frequency of the two dipoles) and the line connections are reversed between successive dipoles, the effect being to produce a main beam directed towards the input end of the line. The present invention provides a microstrip antenna having some analogy to the log periodic dipole array but producing a main beam which is normal to the microstrip ground-plane, and having an important distinction, viz the use of non-direction coupling.

According to the present invention a microstrip antennas which is at least approximately independent of frequency over a wide band comprises:

a microstrip board comprising a dielectric substrate having a conductive feed-line on a first side thereof and a conductive ground-plane on its second side;

a plurality of conducting sheet radiators on said board which are spaced along said feed-line and coupled thereto by at least approximately equal non-direct couplings;

each successive radiator (starting from the input end of the feed-line) being resonant at a frequency which is lower than that of its predecessor;

and each radiator being spaced along the line from its predecessor by such a distance as to radiate approximately in phase with its predecessor.

By "equal non-direct couplings" is meant couplings in which there is no DC connection between the radiators and the feed-line (in particular, coupling cannot be by subsidiary feed-lines) and in which the ratios of the power radiated by each radiator to the power travelling along the feed-line at its coupling position are equal.

Each successive radiator may be resonant at a frequency which is lower by a constant factor than that of its predecessor.

The conducting sheet radiators may be located on the surface of the board in the same plane as the feed-line alongside the feed-line; alternatively, they may be separated from said plane by a dielectric layer with part of each radiator overlying the feed-line.

The radiators may be substantially rectangular. The radiators may be aligned to resonate with their electric vectors substantially normal to the feed-line, in which case successive radiators may be located on alternate sides of the line and be coupled thereto at approximately half-wavelength intervals along the line (said intervals being related to the mean resonant frequency of each adjacent pair of radiators). Alternatively the radiators so aligned may all be located on the same side of the feed-line and be coupled thereto at approximately wavelength intervals (similarly related to the radiator resonant frequencies).

The radiators may alternatively be aligned to resonate with their electric vectors substantially parallel to the feed-line, in which case successive radiators are be located on the same side of the feed-line at approximately wavelength intervals.

Where successive radiators are located on alternative sides of the feed-line, the feed-line may meander laterally so that all the radiators are located substantially symmetrically about a common axis.

Where part of each sheet radiator overlies the feedline, separated therefrom by a dielectric layer, the layer thickness may increase progressively from the input end of the feed-line, in order to tend to equalise the coupling between the feed-line and each radiator. The increase may be stepwise but is preferably linear.

Similarly, whether the radiators are in the plane of the feed-line or overlie it, the thickness of the microstrip substrate may increase progressively from the input end of the feed-line, and likewise the width of the feed-line itself. Thus all dimensions (not only the radiator dimensions, spacings and dielectric layer thickness) may scale with frequency along the line and by the same factor, in order to optimise the bandwidth.

To enable the nature of the present invention to be more readily understood, attention is directed by way of example, to the accompanying drawings wherein:

Figure 1 is a diagram of a known log periodic dipole- array.

Figures 2-6 are plan views of five different forms of microstrip antenna embodying the present invention.

Figures 7 and 8 are sections through two different forms of microstrip antenna embodying the present invention.

Figure 9 is a plan view of the antenna shown in section in Figure 8.

In Figure 1 is shown a known arrangement comprising a plurality of centre-fed dipoles 1 connected in shunt along a two-wire transmission line 2. The successive dipole length L increases progressively from the input-end 3 of the line, and likewise the spacing between successive dipoles, such that

$$\frac{L_n}{L_{n-1}} = \frac{d_n}{d_{n-1}} = T = \frac{f_{n-1}}{f_n} < 1$$

where f is the resonant frequency of the relevant dipole. Additionally, the line connections to the dipoles are reversed between successive dipoles as shown to give a 180° phase-shift and the spacing d between adjacent dipoles is made one quarter wavelength related to the mean frequency of each pair of adjacent dipoles.

The above arrangement is known as a log periodic dipole array. Its response is substantially independent of input frequency within a given band and it produces a beam directed in the plane of the dipoles towards the input-end 3 of line 2. Without going into mathematical theory, its manner of operation is briefly that those dipoles which are of resonant length at or near the input frequency extract power from the transmission line and radiate it. By contrast those of shorter length merely load the line but do not radiate, while the longer dipoles do not have significant power incident upon them. The geometry of a given array is specified by the factor T and the angle α.

In Figure 2 a microstrip board 4 of dielectric material, eg of glass-loaded PTFE such as R.T. Duroid, has its underside (not shown) coated with metal to form a ground-plane. On its upper surface is formed, eg by etching, a metallised feed-line 5 having an input-end 6. Formed alongside line 5 are a plurality of sheet radiators 7 of rectangular form, aligned with their long sides normal to line 5 and their short sides close thereto to effect coupling to the line. The sheet radiators 7 increase in size from the input end of the line so that their successive resonant frequencies, with the electric vector E normal to line 5, decrease by a constant factor T in a manner analogous to Figure 1. In the microstrip case however, the coupling to the feed-line cannot be reversed in the manner of Figure 1, and reversal is obtained by locating successive radiators on alternate sides of the line. Moreover, contrary to Figure 1 the beam is required to be directed normal to the plane of the board 4. This is achieved by making the spacing of the coupling positions between adjacent elements approximately a half wavelength in the feed-line instead of a quarter wavelength as in Figure 1, related to the mean resonant frequency of each pair of adjacent radiators, so that adjacent radiators radiate approximately in phase. Although the arithmetic mean frequency may be used, ideally it should be the logarithmic mean frequency, ie obtainable by plotting their frequencies on a log scale and bisecting the distance between them on the scale. However the exact spacing is a matter of experiment to obtain the optimum performance, as is also the case in the subsequently described embodiments. The coupling is controlled by the line-to-radiator spacing. In principle the feed-line may be left open-circuited beyond the largest radiator, but may be terminated with a matched load in order to prevent reflections degrading the radiation patterns at the edge of the frequency band covered by the antenna.

In Figure 3 the rectangular sheet radiators 8 are aligned with their long sides parallel to the line 5 so that their E-vectors are likewise parallel thereto. With this alignment the coupling to the radiators cannot be reversed simply by locating successive radiators on alternate sides of the line as in Figure 2, and therefore to make adjacent radiators resonant approximately in phase d is made a full wavelength. All the radiators need not be on the same side of the line as shown, eg they can alternate as in Figure 2 provided the full wavelength spacing of the coupling positions is maintained.

Reverting to Figure 2, the radiators 7 can likewise all be located on the same side of line 5 if they are coupled a full wavelength apart instead of a half wavelength.

In Figure 4 the radiators 13 partially overlie the line 6, being separated therefrom by a layer of dielectric material (not shown) in the manner described by H.G. Oltman in US Patent No 4,054,874 and in his paper "Electromagnetically coupled microstrip dipole antenna elements" (Proc 8th European Microwave Conference, Paris, Oct 1978, pp281-285). Opposite ends of adjacent radiators overlie the line so that the arrangement is electrically similar to Figure 2 and the radiator spacing d is a half wavelength.

In Figure 5 the radiators 14 are coupled similar to those of Figure 4 but the line 5 meanders laterally so that the radiators are symmetrical about a common axis 15. The inter-radiator spacing d is again a half wavelength (measured along line 5, not along axis 15). A meandering line may also be usable in earlier-described embodiments, eg Figures 2 and 4, to align the radiators symmetrically, where dimensions permit.

Figure 6 is similar to Figure 4 except that similar ends of adjacent radiators 16 overlie the line and the spacing d is thus a full wavelength.

The form of coupling shown in Figures 2 and 3 enables low coupling to be achieved, and has one application in arrays where the angle α is small and the power is removed from the feed-line progressively over several radiators so that a narrow beam is thereby produced. The overlying arrangements of Figure 4-6

thereby enabling broad- or narrow-beam arrays to be produced.

In overlying arrangements, eg in Figures 4-6, the available coupling to the smaller radiators, ie those of higher resonant frequency, becomes limited unless the thickness of the dielectric layers separating the radiator from the feed-line is reduced. At lower frequencies the coupling is adequate, but the bandwidth of the individual resonators becomes small and either the input match tends to become peaky or, to avoid the latter, more radiators are needed in a longer array (small α) with a consequent narrowing of the beam-width. Figure 7 shows an arrangement which alleviates this difficulty.

Note that in the present invention the radiator dimension chosen to set the angle α can be selected arbitrarily for any specific form of the invention, eg in Figures 2, 4, and 6 it is shown selected as the distance from the feed-line to corresponding corners of the radiators. In the preceding two paragraphs, the variation in α refers to the variation in such an arbitrarily selected α for any specific form.

Figure 7 shows a microstrip board comprising dielectric material 4 having on its underside a ground-plane 18 and on its upper surface a feed-line 5. Partially overlying line 5, as in Figures 4-6, is a plurality of radiators 20 of progressively increasing size and spacing as already described. The dielectric layers which separate the radiators from the line are successively stepped in thickness as shown at 21, 22 and 23 in order to maintain approximately equal coupling between the successive radiators and the line and thereby increase the bandwidth.

Preferably the dielectric layer thickness increases linearly rather than stepwise, as shown in Figure 8 at 24, and desirably the thickness of the microstrip dielectric material 4 likewise increases linearly as shown. Additionally, as shown in Figure 9, the feed-line 19 may increase linearly in width. In this way all the antenna dimensions can be made to scale with frequency by the same factor T (not only the radiator dimensions and spacings as already described), resulting in a closer approach to true log periodic performance over a theoretically infinite bandwith. A linearly increasing microstrip dielectric thickness, as at 4 in Figure 8, and linearly increasing feed-line width as in Figure 9 can also be used in those embodiments where the radiators are in the same plane as the feed-line, eg as in Figures 2 and 3 to give improved (theoretically infinite) bandwidth.

By way of example results are given below for an example of the embodiment of Figure 4, using uniform thickness dielectric in the microstrip board 4 and uniform thickness dielectric layers separating the radiators 13 from the feed-line 5, which was of uniform width. The spacing d was not exactly a half wavelength but was optimised for best performance, as was the position of each radiator relative to the feed-line in the direction transverse thereto.

Bandwidth	:	26%
VSWR	:	$<2.3:1$
Gain	:	>10 dB
Beam-width	:	28 to 34°
Frequency	:	8 to 10.6 GHz
Polarisation	:	Linear
Efficiency	:	approx 80%

Constructional details were:
Microstrip dielectric material. RT Duroid (glass-loaded PTFE), 0.8 mm (1/32 inch) thick.
Feed-line width: 2.5 mm
Dielectric spacing layer material: RT duroid, 0.8 mm thick.
Number of radiators: 9
Radiator dimensions: from 10.6 × 10.3 mm to 7.0 × 6.8 mm with T approx 0.95.

Although in the above-described embodiments the factor T by which the resonant frequency of successive radiators decreases is assumed constant, the invention is not limited to such arrays. For example in other forms of the invention the factor T may itself be made to change progressively along the array from the input end in a manner which offsets the unequal coupling effects due to the use of constant-thickness dielectric material in either the microstrip board 4, or in the overlying dielectric layers described with reference to Figures 4-6, or in both.

It will be observed that, in contrast to the log periodic dipole array, the present invention precludes direct connection between the radiators and the feed-line. This important distinction arises because the equivalent lumped circuits of a dipole and a sheet radiator are different, being respectively series and parallel tuned circuits. It can be shown that because of this difference, direct connection of the sheet radiators to the feed-line, as by short subsidiary feed-lines, would result in those resonators at the input end of the antenna tending to act as short-circuits when off resonance, thereby inhibiting power from reaching subsequent resonant radiators.

The present invention is to be contrasted with the antennas shown in UK Patent Specification No. 1,294,024, which discloses antennas comprising a plurality of conducting patch radiators spaced alongside microstrip feed-lines. Apart from Figure 8 thereof, all radiators in these antennas have the same resonant

two different frequencies. There is no teaching of a wide-band log periodic arrangement such as is provided by the present invention.

CLAIMS

1. A microstrip antenna which is at least approximately independent of frequency over a wide band comprising:

a microstrip board comprising a dielectric substrate having a conductive feed-line on a first side thereof and a conductive ground-plane on its second side;

a plurality of conducting sheet radiators on said board which are spaced along said feed-line and coupled thereto by at least approximately equal non-direct couplings (as hereinbefore defined);

each successive radiator (starting from the input end of the feed-line) being resonant at a frequency which is lower than that of its predecessor;

and each radiator being spaced along the line from its predecessor by such a distance as to radiate approximately in phase with its predecessor.

2. An antenna as claimed in claim 1 wherein each successive radiator is resonant at a frequency which is lower by a constant factor than that of its predecessor.

3. An antenna as claimed in claim 1 or claim 2 wherein the radiators are located on the board in the same plane as the feedline alongside the feedline.

4. An antenna as claimed in claim 1 or claim 2 wherein the radiators are separated from the plane of the feed-line by a dielectric layer with part of each radiator overlying the feed-line.

5. An antenna as claimed in any of claims 1 to 4 wherein the radiators are substantially rectangular.

6. An antenna as claimed in any of claims 1 to 5 wherein the radiators are aligned to resonate with their electric vectors substantially normal to the feed-line, successive radiators being located on alternate sides of the line and being coupled thereto at approximately half-wavelength intervals along the line (said intervals being related to the mean resonant frequency of each adjacent pair of radiators).

7. An antenna as claimed in any of claims 1 to 5 wherein the radiators are aligned to resonate with their electric vectors substantially normal to the feed-line, successive radiators being located on the same side of the feed-line and coupled thereto at approximately wavelength intervals (said intervals being related to the mean resonant frequency of each adjacent pair of radiators).

8. An antenna as claimed in any of claims 1 to 5 wherein the radiators are aligned to resonate with their electric vectors substantially parallel to the feed-line, successive radiators being located on the same side of the feed-line at approximately wavelength intervals (said intervals being related to the mean resonant frequency of each adjacent pair of radiators).

9. An antenna as claimed in claim 6 wherein the feed-line meanders laterally so that all the radiators are located substantially symmetrically about a common axis.

10. An antenna as claimed in claim 4 and in any of claims 5 to 9 as dependent on claim 4, wherein the thickness of said separating dielectric layer increases progressively from the input end of the feed-line, whereby to tend to equalise the coupling between the feed-line and each radiator.

11. An antenna as claimed in claim 10 wherein said thickness increases stepwise from radiator to radiator.

12. An antenna as claimed in claim 10 wherein each successive radiator is resonant at a frequency which is lower by a constant factor than its predecessor and wherein said thickness increases linearly along the feed-line.

13. An antenna as claimed in any of claims 2 to 12 wherein the thickness of the dielectric substrate increases linearly along the feed-line from its input end.

14. An antenna as claimed in claim 12 wherein the width of the feed-line increases linearly from its input end.

15. A microstrip antenna substantially as hereinbefore described with reference to Figures 2 to 9 of the accompanying drawings.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1981.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.